Beneficial Uses of CO_2

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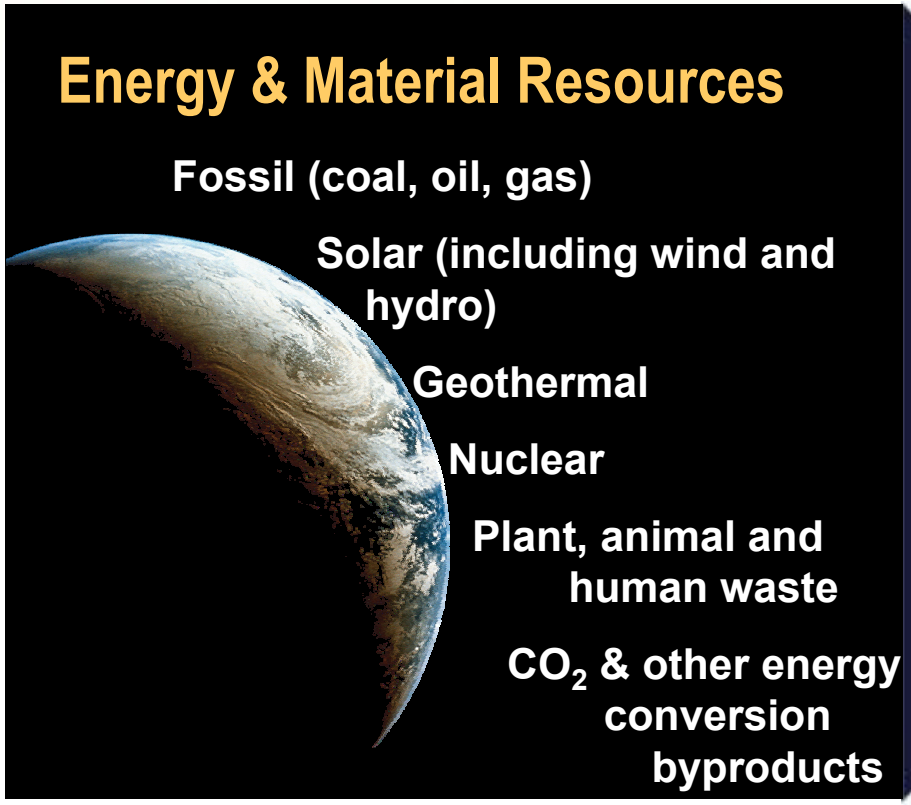
Harvest, Transform, and Control Delivery of Available Energy



*EXERGY = AVAILABLE ENERGY = useful portion of energy that allows one to do work and perform energy services

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CO_2 Mitigation Strategies

- Reduce or eliminate CO_2 production
  - Requires new technology and infrastructure for energy production
- Capture and sequester CO_2 - Treat CO_2 as waste
  - Enormous volumes difficult to store
    - For example ~4 cubic kilometer/year if CO_2 from petroleum captured as solid $CaCO_3$
- Capture and reuse CO_2 - **Make CO_2 a Resource**
  - CO_2 has value and can be recycled
  - New technology needed, but augments existing infrastructure

How to capture the CO_2?

- Two major possibilities
  - Capture it at the source
    - Most practical for stationary sources
    - Easiest with pure oxygen combustion
  - Remove it from the atmosphere
    - Challenging, but not impossible
    - Wind naturally moves vast quantities of air
    - Feasible to build scrubbers that to pull CO_2 directly from air
    - Potential to disconnect capture from source

What could we do with CO_2?

- Possible uses for CO_2:
  - Building materials
  - Production of fertilizer
    - Largest use now, ~9 million Mt
  - Enhanced oil recovery
    - ~90% CO_2 sequestered 'permanently
    - Roughly carbon neutral for oil recovered
  - Convert it back to fuels
- A practical consideration:
  - There's a lot of CO_2 to deal with
    - 2004: US = 6 billion Mt, World = 27 billion Mt
    - There are very few things we use at this scale, except fuel

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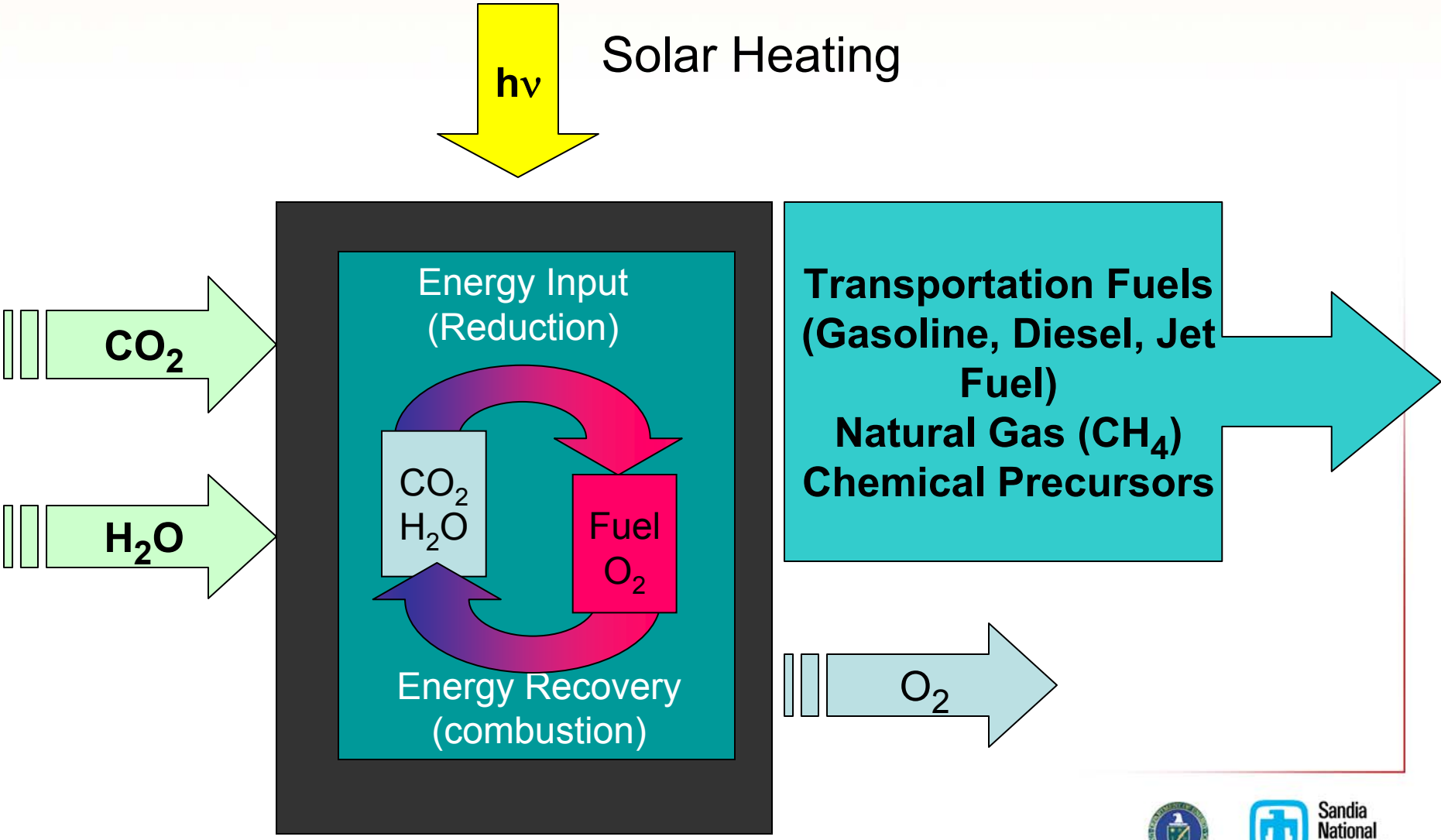
Only Fuel Scales to CO_2 Problem

- 'Problem' CO_2 came from fuels
- In principle, it can be recycled

- BUT, where does the energy come from to convert CO_2 back to fuel?
  - Solar
  - Nuclear

Solar Driven CO_2 to Fuel



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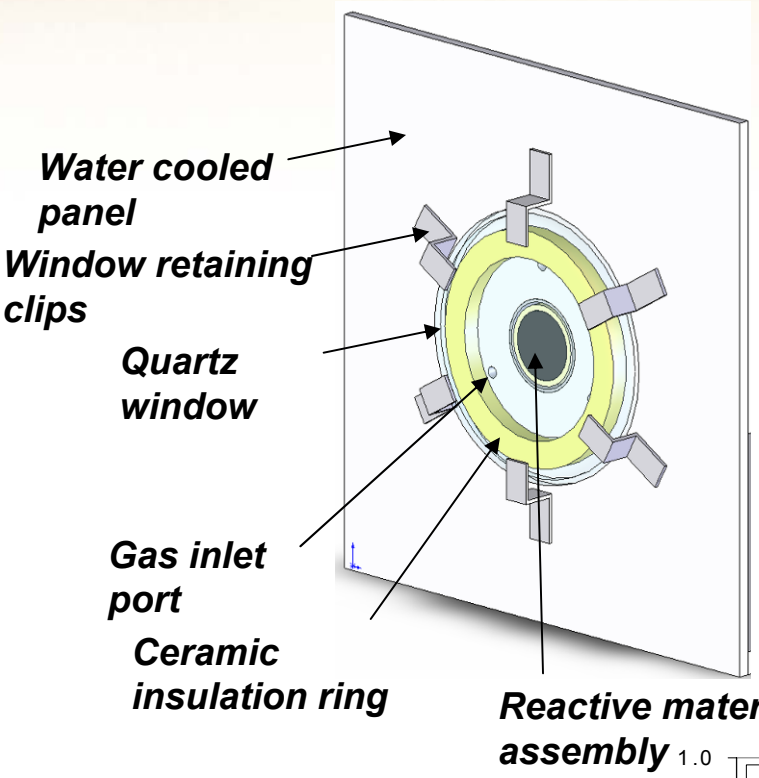
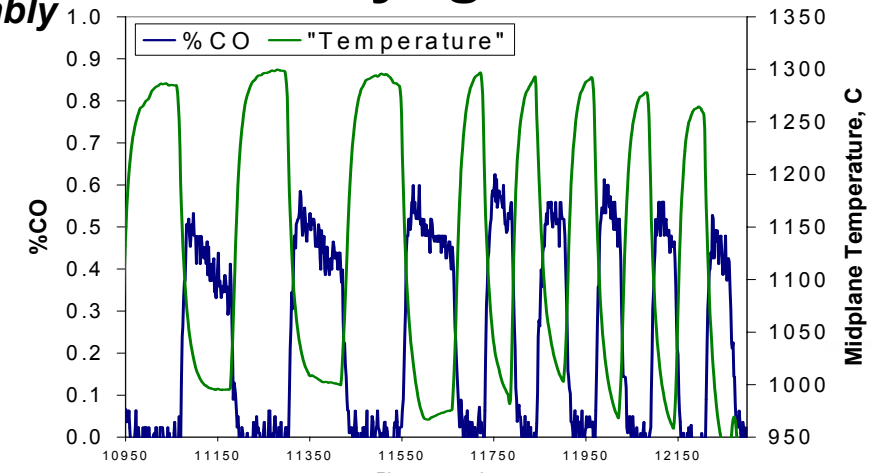
CO_2 Splitting Shown Feasible



- **Two materials classes have demonstrated the ability to split both H_2O and CO_2**
- **Making both H_2 and CO give Syngas**
- **Known paths to essentially any hydrocarbon fuel from Syngas**



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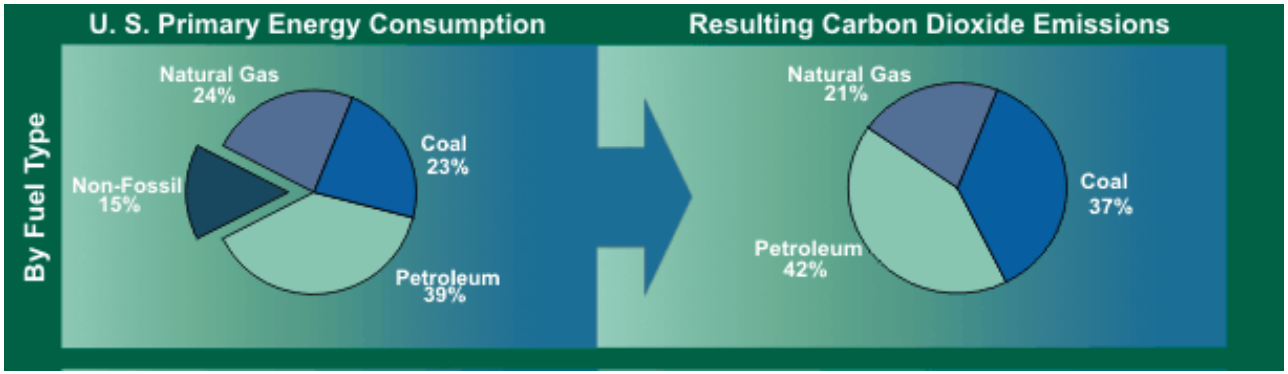
Recycling CO_2 Produces Carbon Neutral Fuel



- **Recycling significantly reduces net C-emissions**: Assuming a Carbon Constrained World, concentrated sources of CO_2 will be available in the relative near-term
  - Coal, Natural Gas, or biomass burning plants
  - Cement Plants
  - **15% penetration - ~7% CO_2 reduction, 70% penetration ~30% reduction**
- Can be made to be nearly **carbon neutral** by separating CO_2 from air

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Recommendations

- Add CO_2 recycle to menu of GHG mitigation activities
- Link in to international efforts
  - International conference on Carbon Dioxide Utilization (ICCDU)
- Support research on CO_2 recycle
- Encourage private sector investments
  - Incentives
  - Markets

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Technically Possible: Moving CO_2 From Liability to Resource

- Technology development needed
  - CO_2 capture development
  - CO_2 to fuel efficiency improvements
- Regulation needed
  - True cost of CO_2 occurs on a timescale incompatible with market forces
  - Regulation is needed to connect these costs on a more immediate timescale

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